



**CSCI 202 Research Methods**

# **Data Visualization**

**L. FELIPE PERRONE**

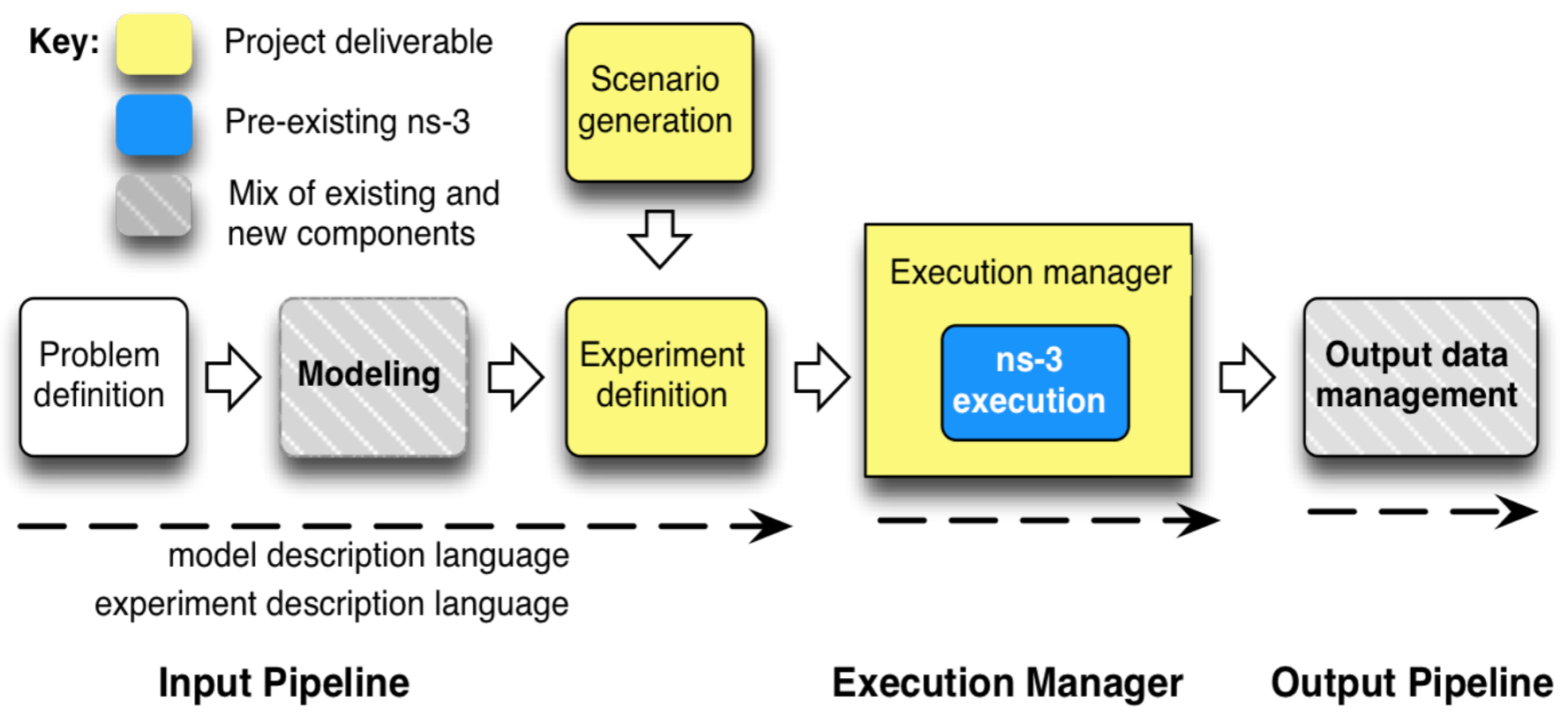
**ns-3** is a free, open source software project building and maintaining a discrete-event network simulator for research and education

## Technical goals:

- Build and maintain a simulation core aligned with the needs of the research community
- Help to improve the technical rigor of network simulation practice

# Frameworks for ns-3

NSF CISE Community Research Infrastructure  
University of Washington (Tom Henderson),  
Georgia Tech (George Riley),  
Bucknell University (L. Felipe Perrone)

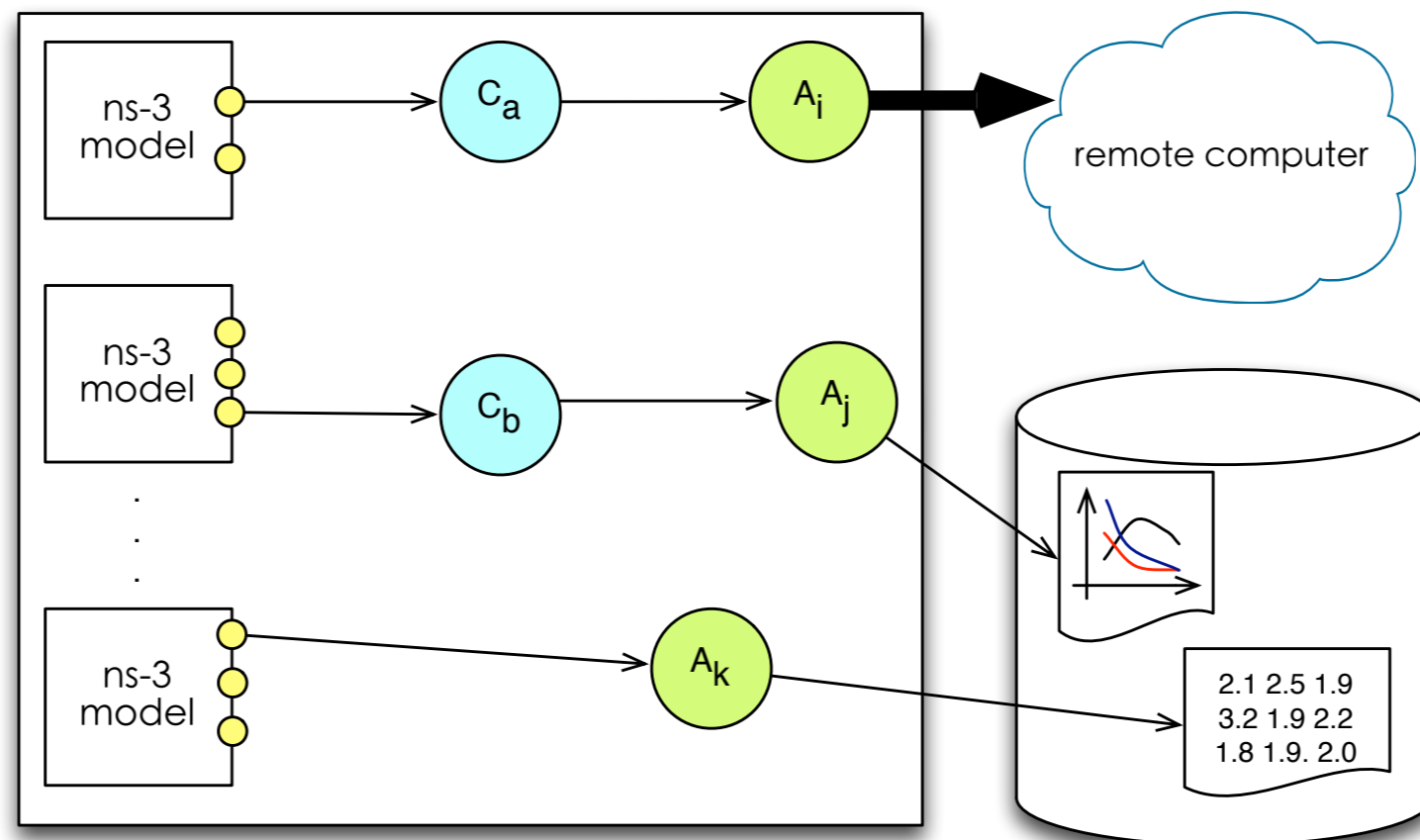


# Visualization for Experienced Users

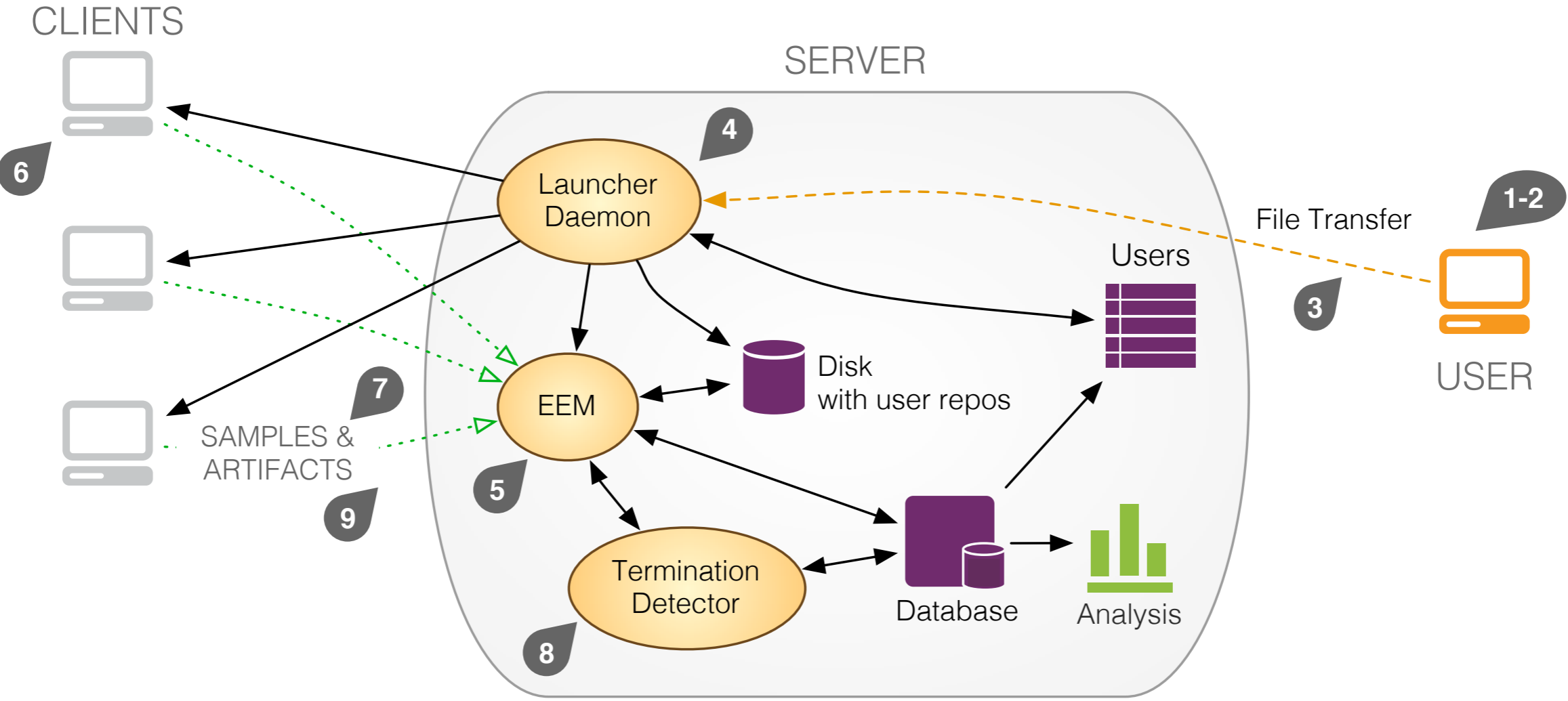
## Data Collection Framework (DCF)

Perrone, Henderson, Watrous, and Felizardo (WSC 2013)

- **DataCollectionObject**: base class for DCF elements.
- **Probe**: extends TraceSources for controllability.
- **Collector**: encapsulates arbitrary computations on sampled data.
- **Aggregator**: marshals data into various output formats.



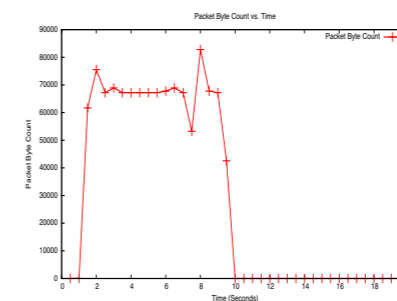
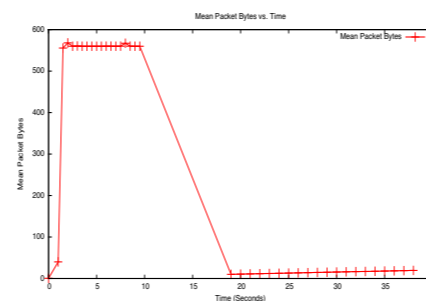
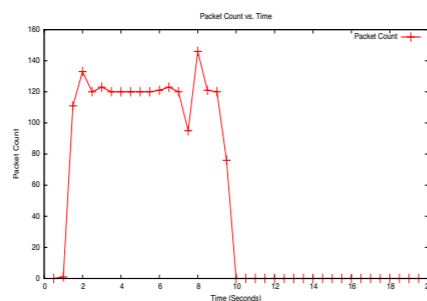
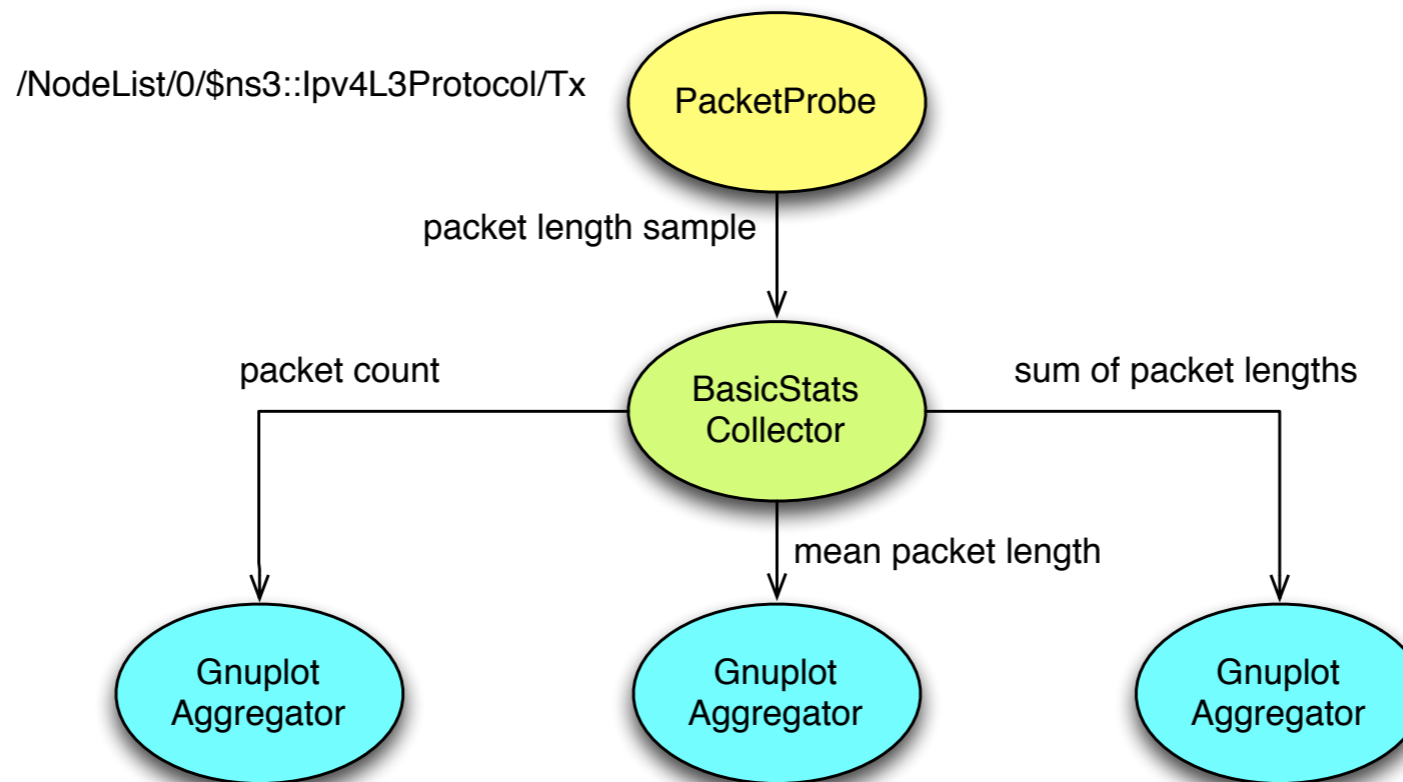
# Simulation Automation Framework for Experiments (SAFE)



Perrone, Main, and Ward (WSC 2012)

# Gnuplot: Aggregator and Helper

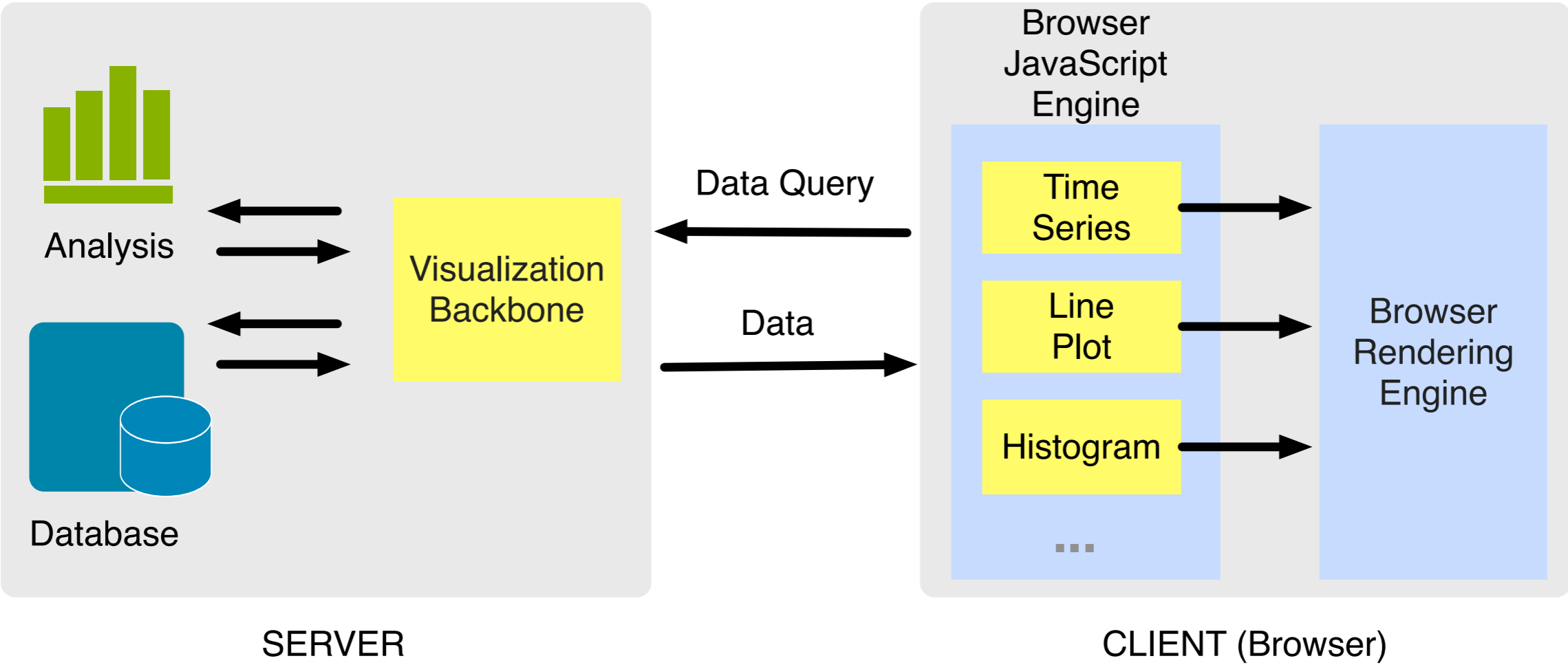
- Address basic visualization needs of the ns-3 user (non-interactive plots)
- Guarantee basic properties of plots
- Create separate files with data and **gnuplot** script
- Uses any format supported by **gnuplot**



# SAFEty Net for Novices

- Offer various types of visualization
- Make retrieval from database easy and powerful
- Automate color selection
- Guarantee complete plot metadata
- Export various file formats (PNG, PDF, ...)
- Constrain choices to best practices
- Web-based UI

# Visualization in SAFE





The point is...

There exists a extensive  
body of knowledge on  
**visualization** that we  
can leverage.

And..

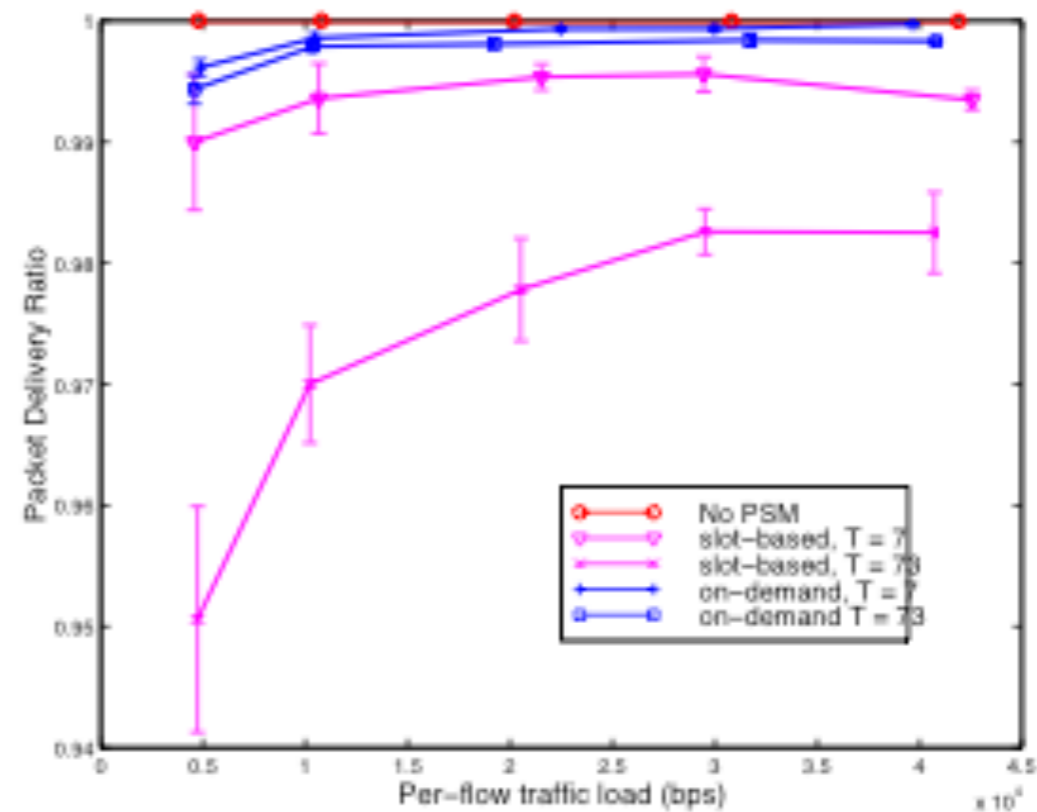
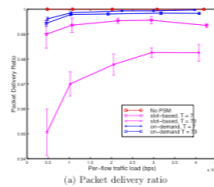
One can incorporate these lessons to put visualization intelligence into visualization tools.

# What is Sometimes Forgotten (Ignored?)

## Human perception

### Retinal Variables (Bertin 2010)

- size
- value
- texture
- color
- orientation
- shape



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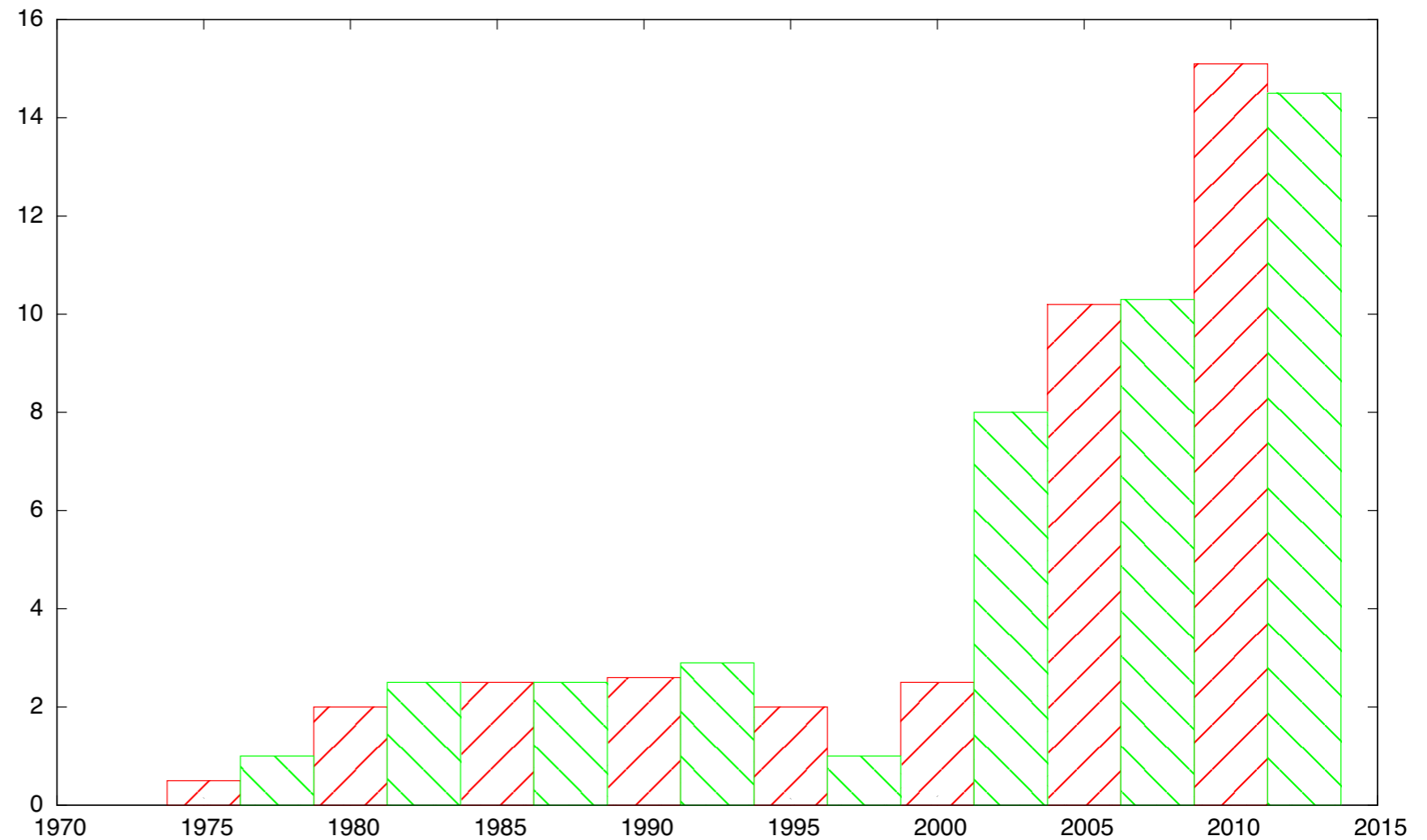


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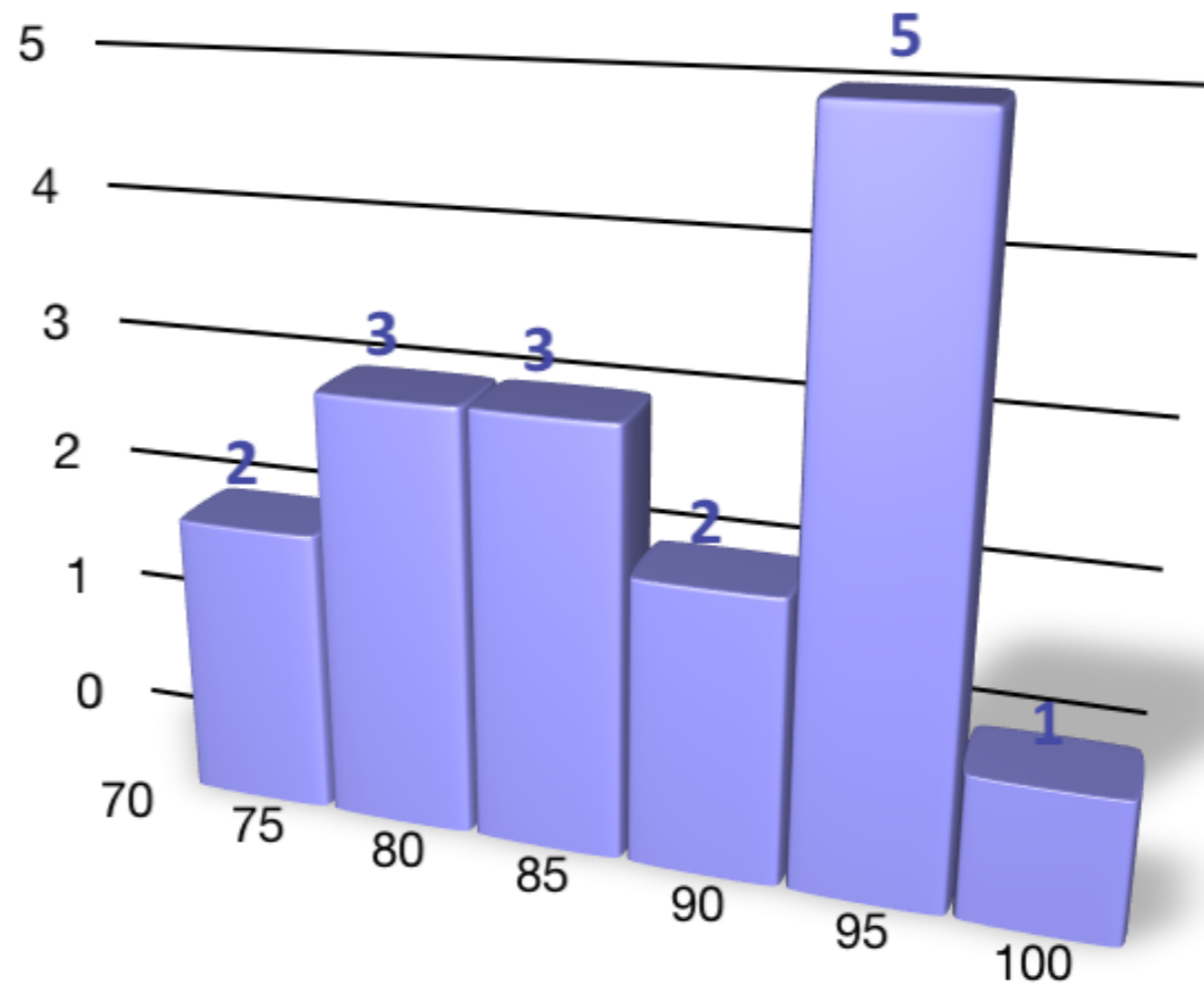


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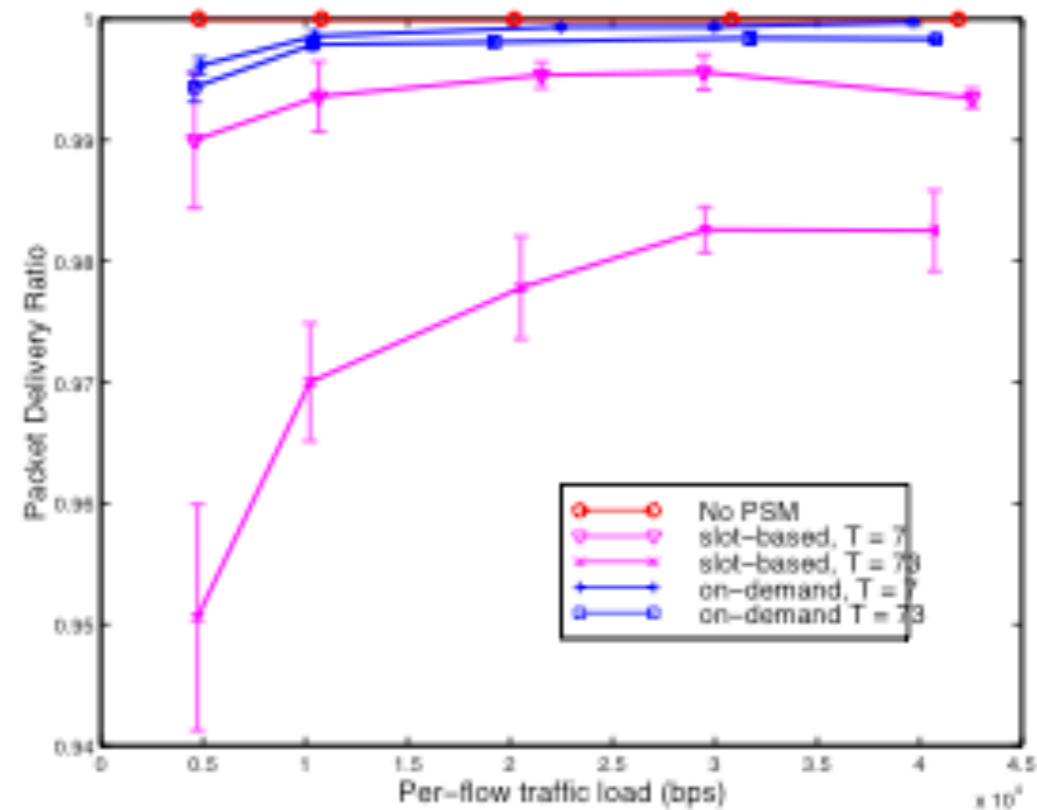
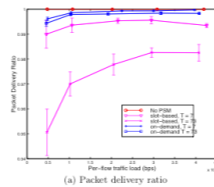


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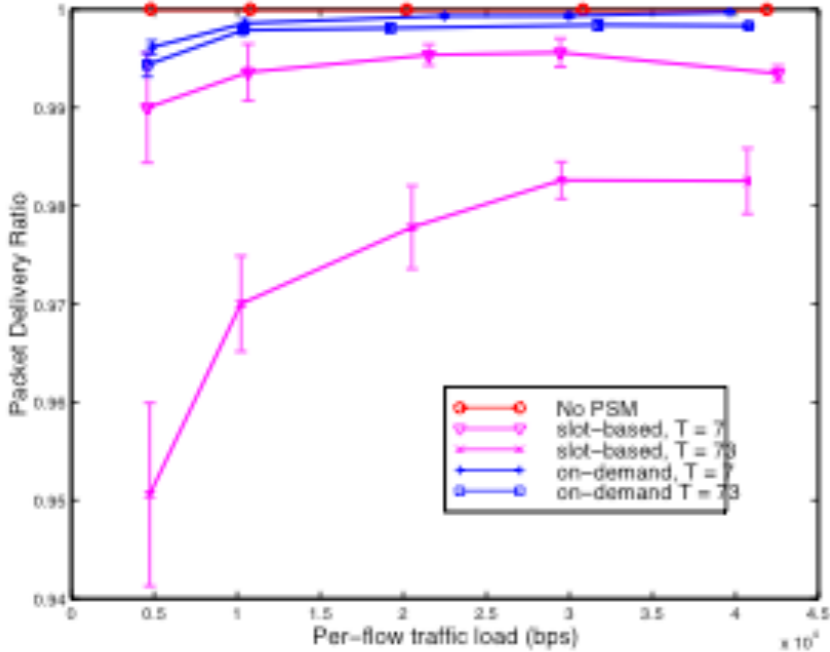
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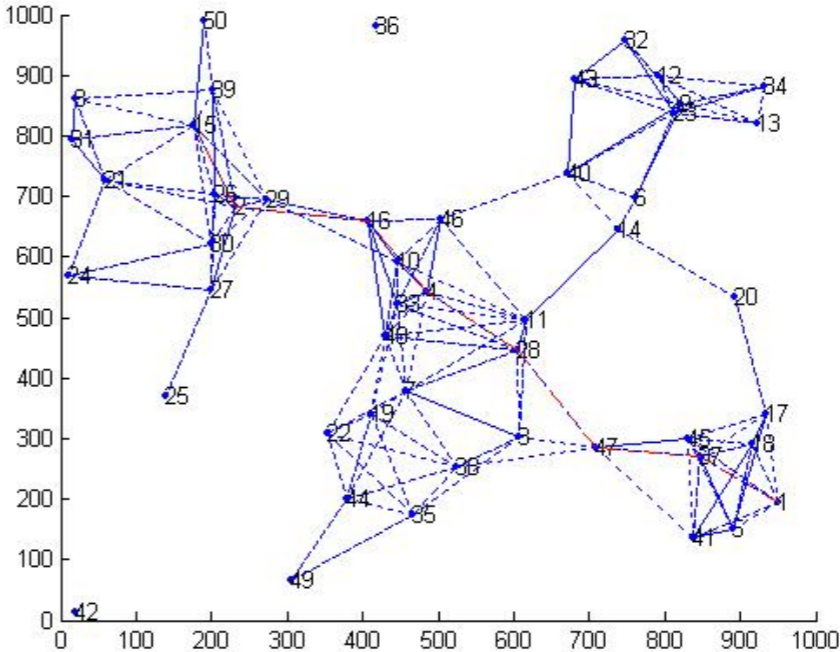
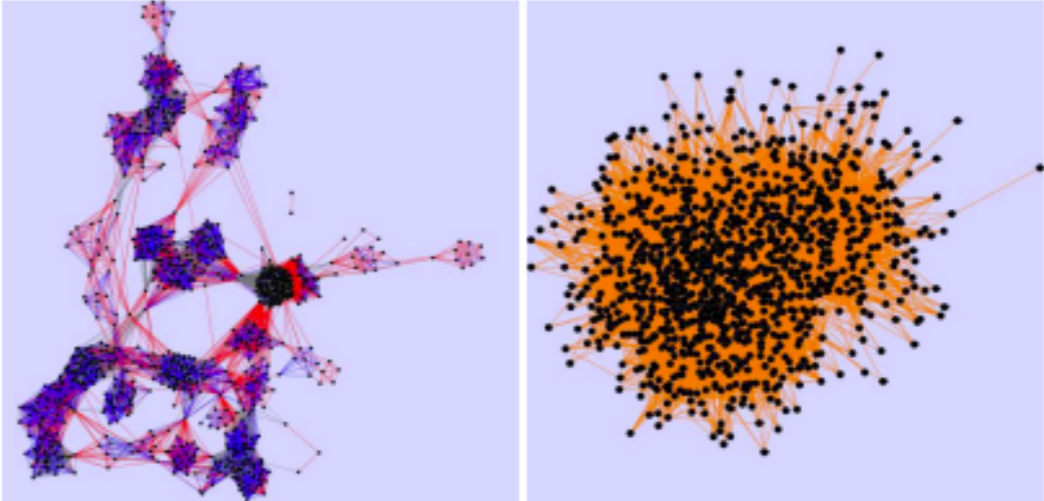
# Visualization Needs of Network Simulation

line plot



(a) Packet delivery ratio

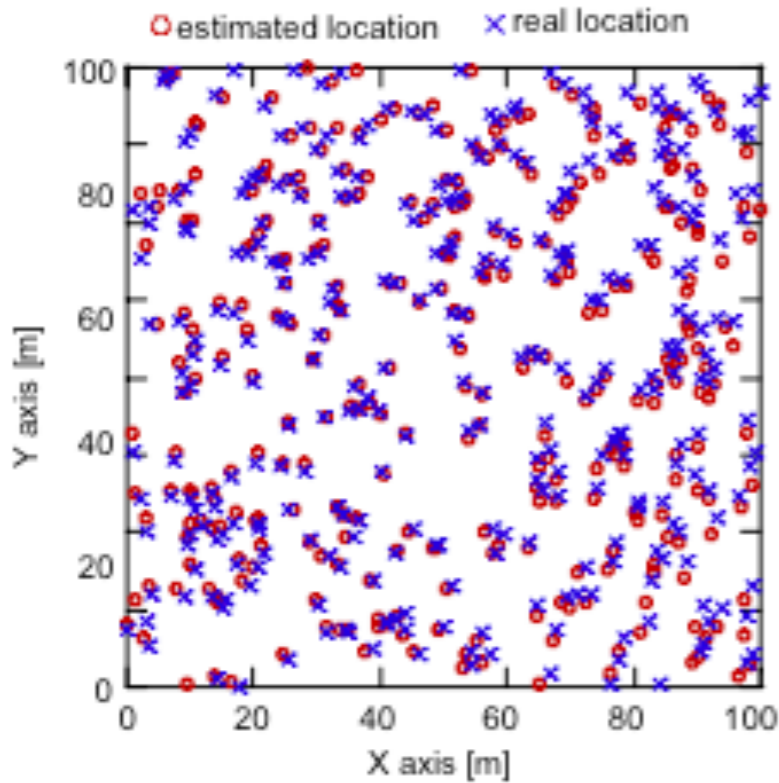
graphs



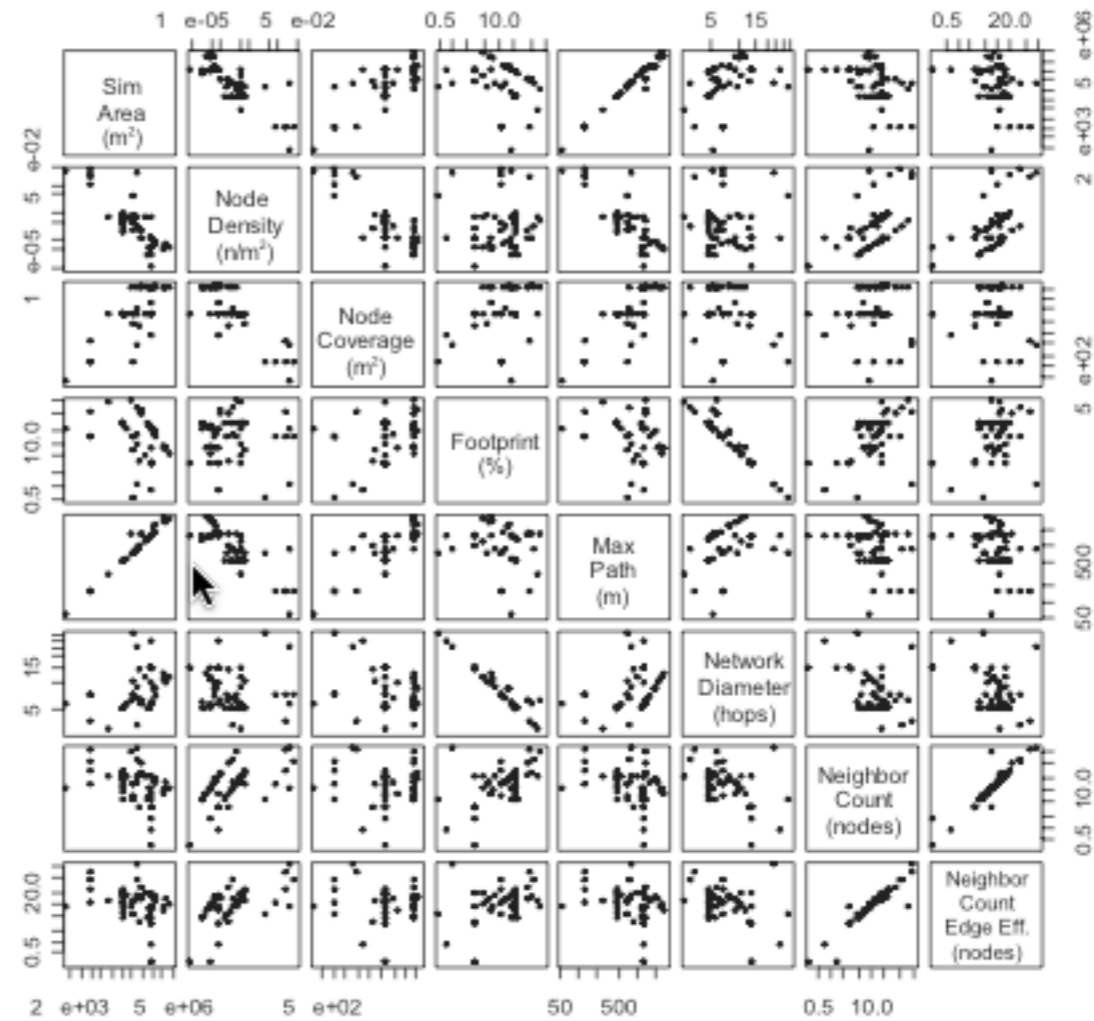


# Visualization Needs of Network Simulation

scatter plot

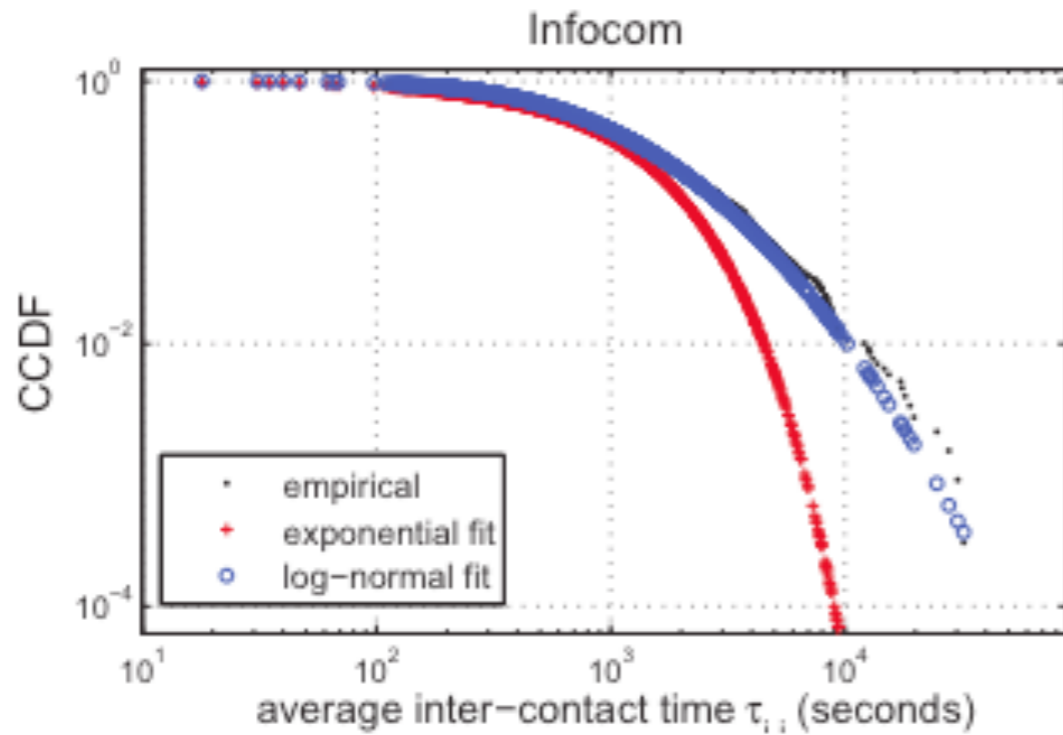


scatter plot matrix

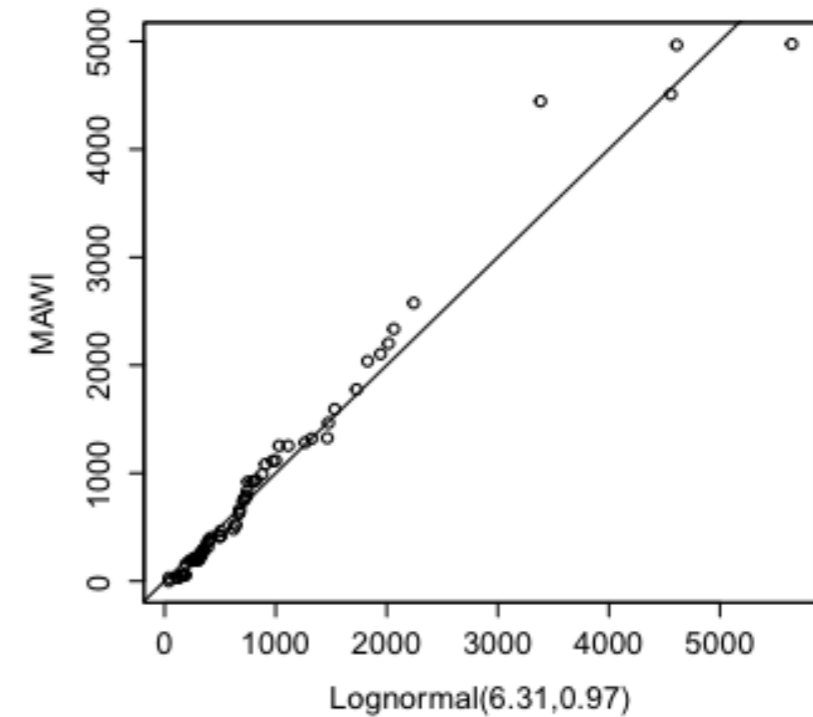


# Visualization Needs of Network Simulation

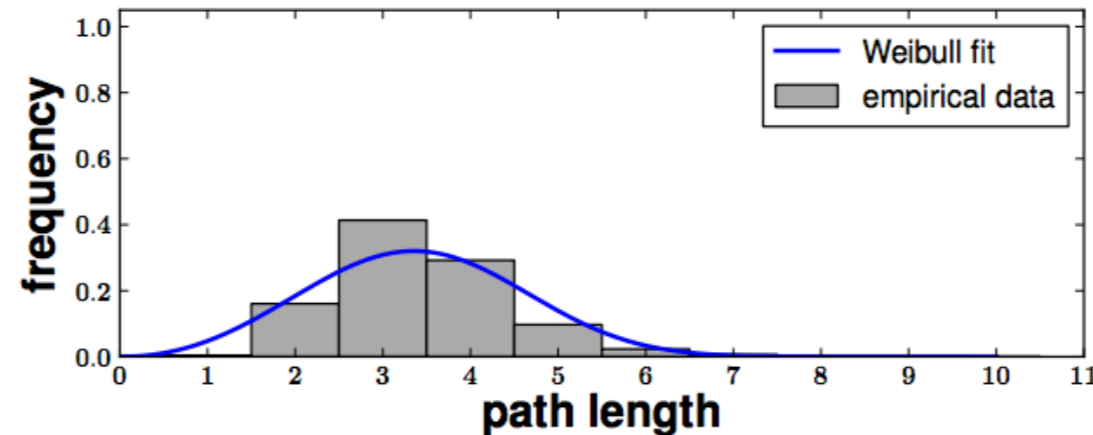
probability distributions



q-q plot

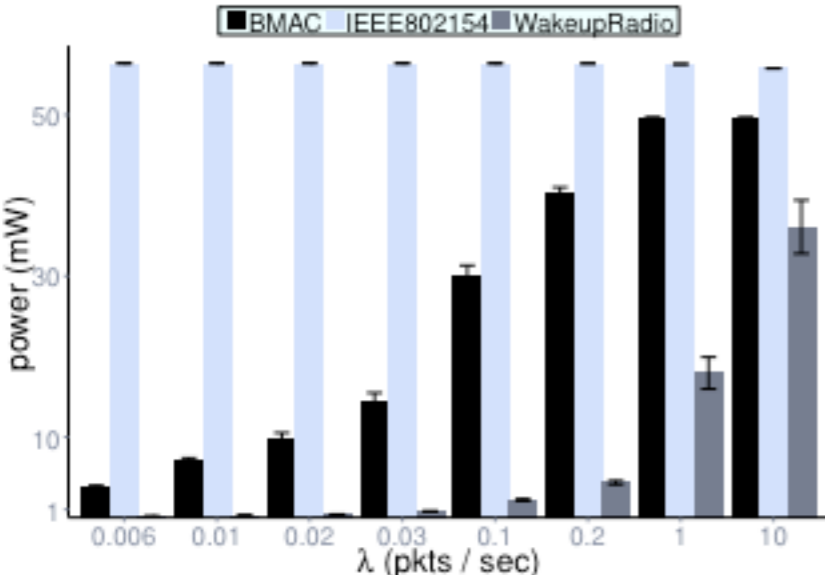


histogram

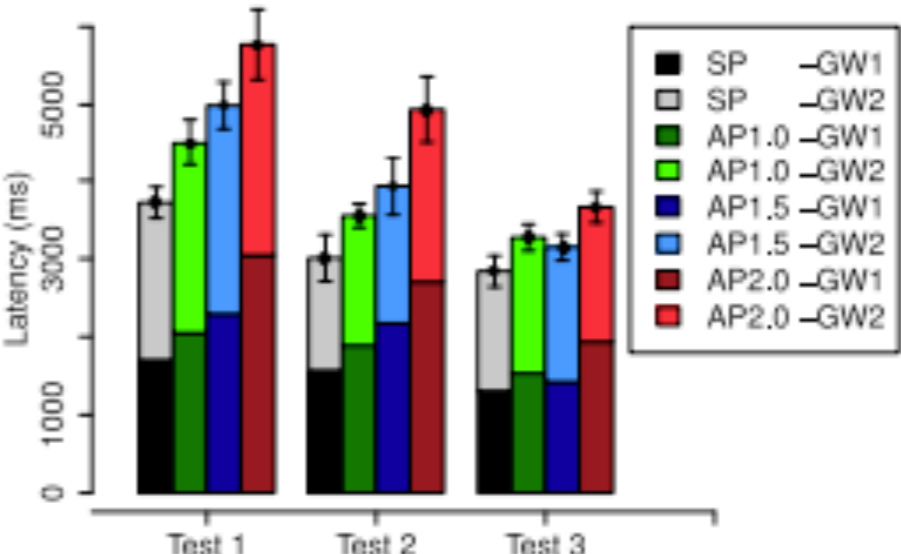


# Visualization Needs of Network Simulation

bar graph



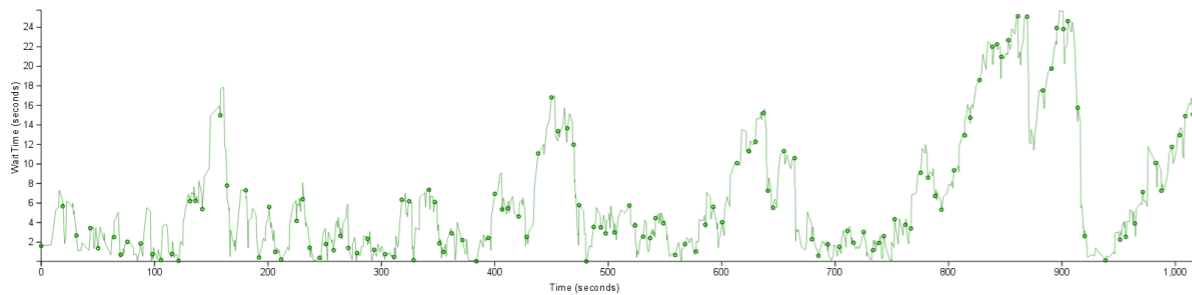
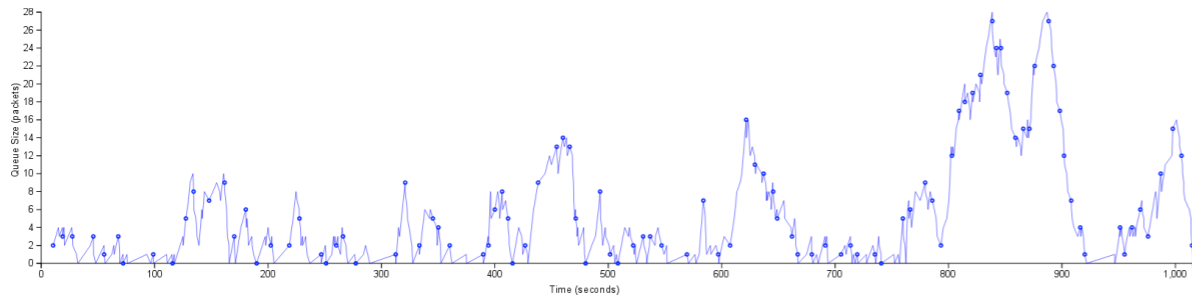
stacked bars



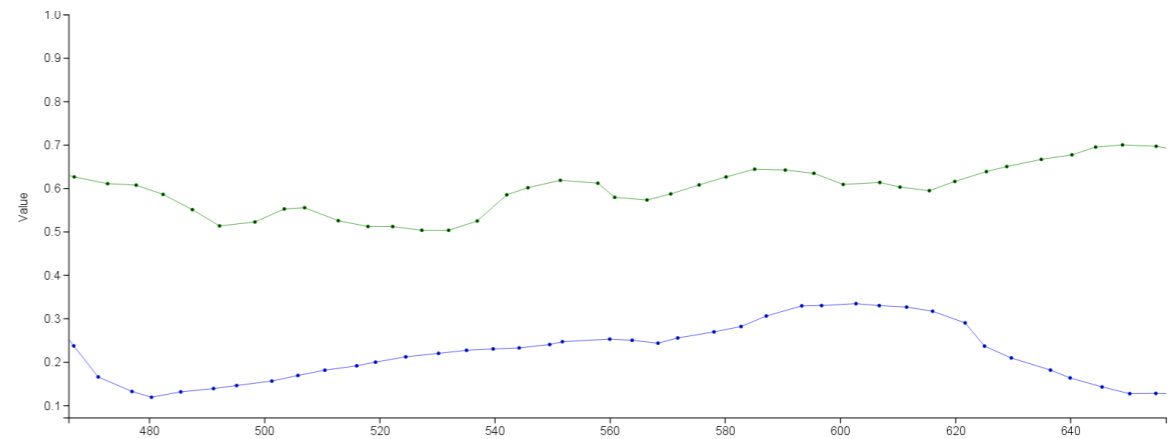
(a) Average latency

# State of Development in SAFE

- Web-based UI: going into a third iteration
- Incorporates database retrieval, filtering, “smoothing”
- Supports for comparisons via:



faceting



normalization

# Control Panel

Experimental factor

Starting level

Ending level

Retrieved design points

Selection of individual run

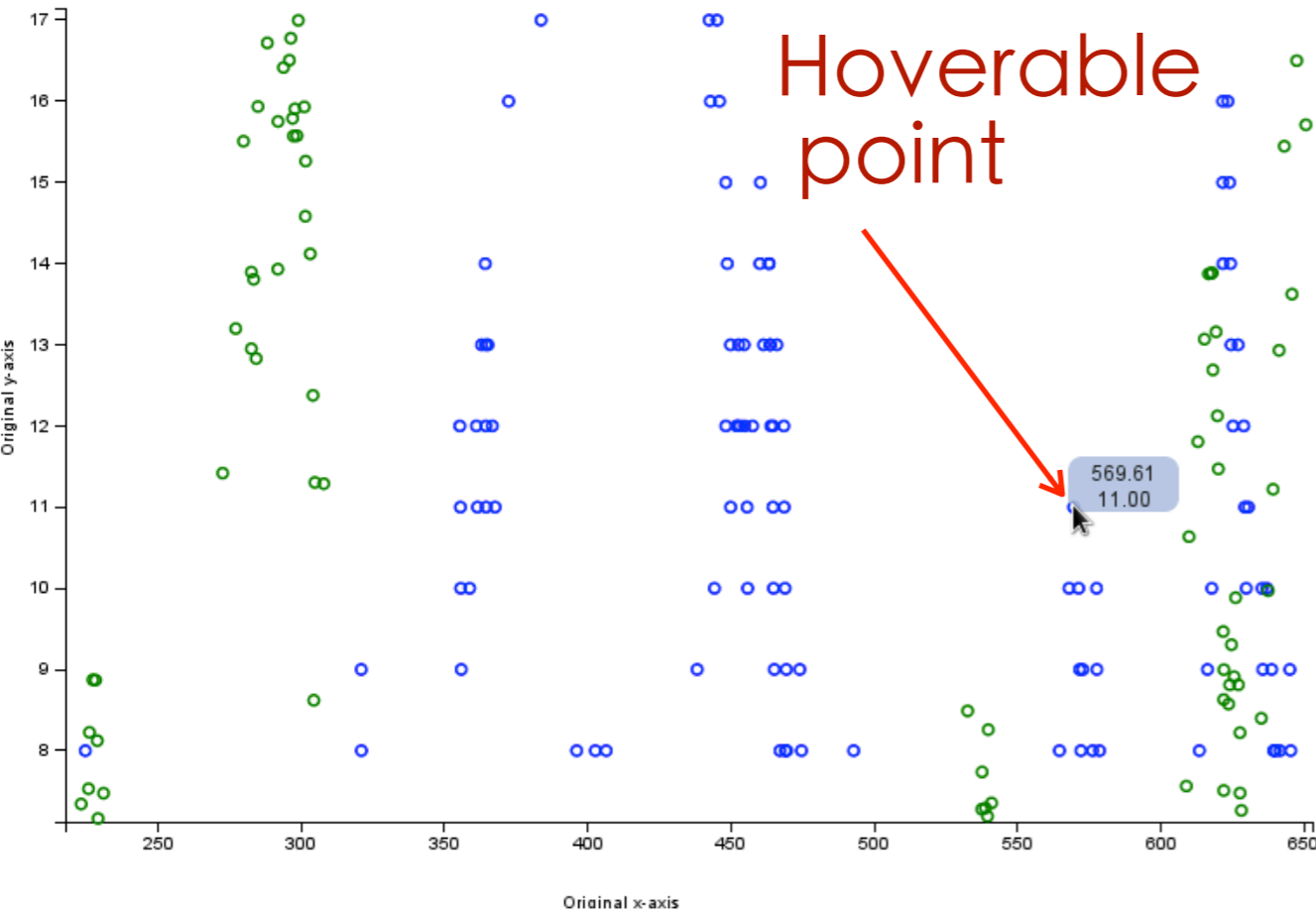
Available output metrics

Filtering/processing options

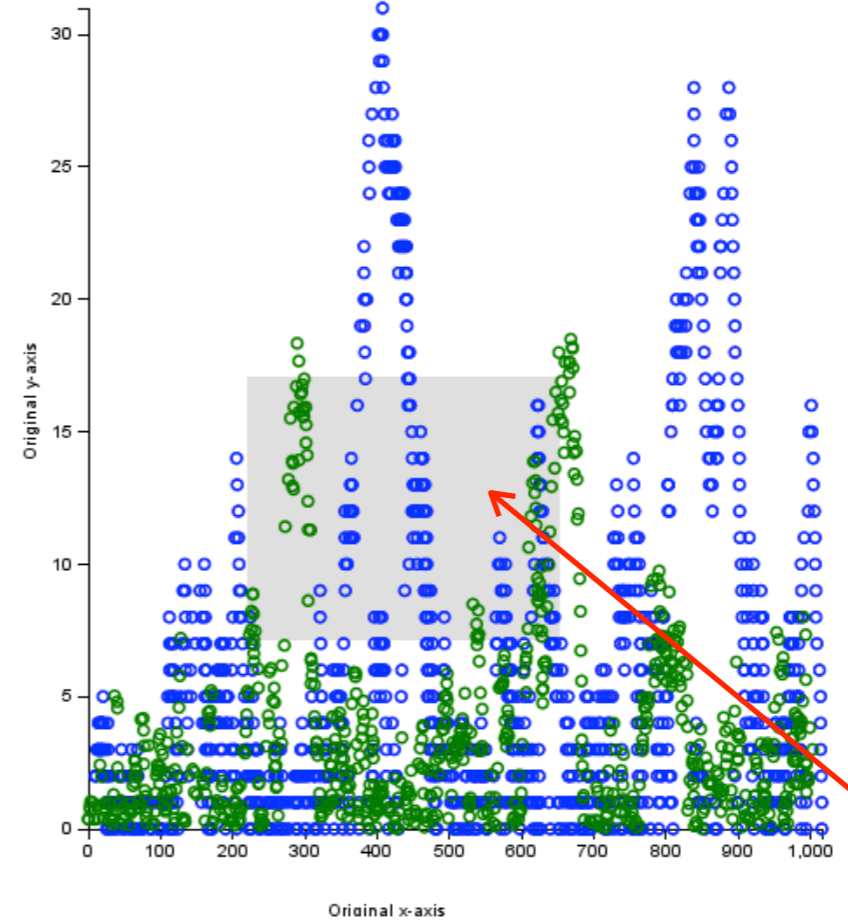
The screenshot shows a 'Select' control panel with the following elements:

- A 'Hide' button at the top left.
- A dropdown menu for 'endTime'.
- Two input fields for '1000000'.
- An 'Apply Selection Filter' button.
- A dropdown menu for 'DesignPoint 32' with sub-values: 'endTime : 1000000', 'interarrival : 0.9', and 'service : 0.7'.
- A dropdown menu for 'Run 3'.
- A list of available output metrics: 'QueueSizeMean' (checked) and 'WaitTimeMean' (unchecked).
- Filtering options: 'Filter Step: 0', 'Max Results: 300', 'Moving Average: 50', and 'Outlier Filter: 0'.

# SAFE Visualization: Scatter plots



Hoverable point



**Select**

interarrival

1 1.3

Apply Selection Filter

DesignPoint 9

Run 32

QueueSizeMean

WaitTimeMean

**Options**

Cross Hairs

Brush

**Display**

X ■ Run 1, Metric: 1

X ■ Run 32, Metric: 2

**Selection Parameters**

X :Factor: interarrival, Range: 1 - 1.3

Focus  
"Micro"

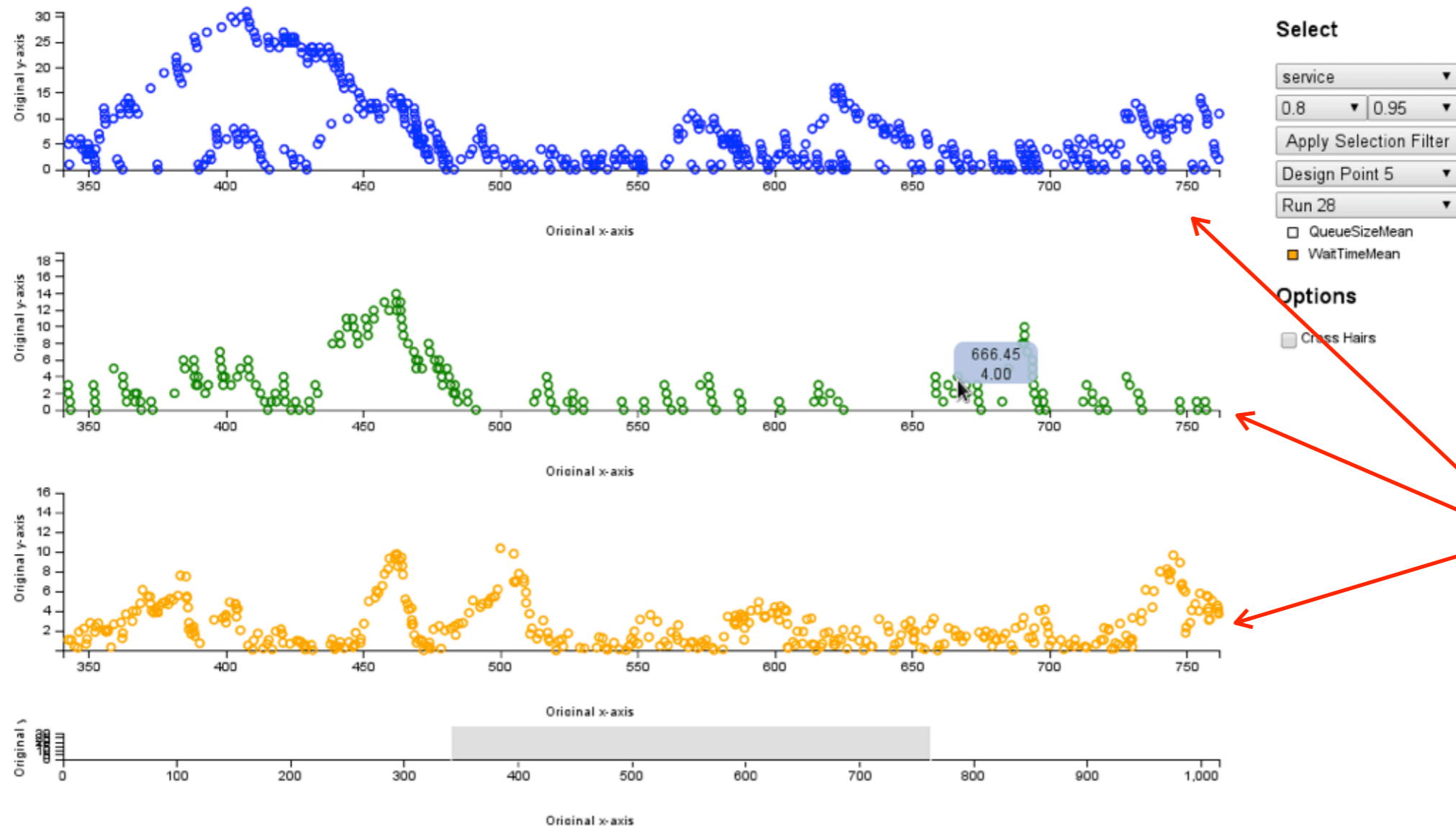
Context  
"Macro"

# SAFE Visualization: Comparing Scatter plots

Scatter Plot (with brush) x Scatter Plot (with brush) x Line Plot x SAFE part of call age d x

hive:8000/visualization/scatter\_faceted/?exp\_id=2

Google Sports MyBucknell Bucknell Databases Dictionary.com - F... Thesaurus.com | ... Pandora Internet ... Sincerely, One of ...



**Select**

service

0.8 0.95

Apply Selection Filter

Design Point 5

Run 28

QueueSizeMean

WaitTimeMean

**Options**

Cross Hairs

Faceting

**Display**

X Run: 1, Metric: 1

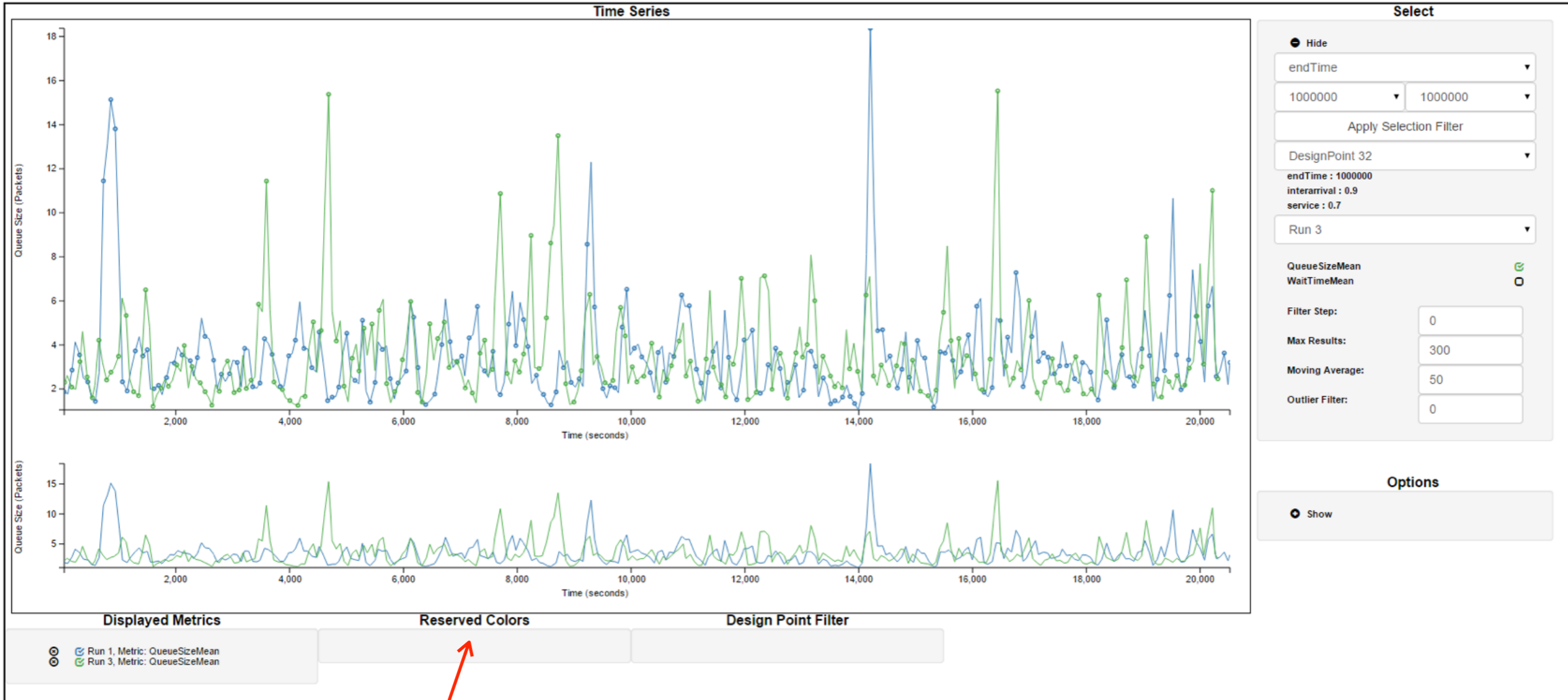
X Run: 28, Metric: 2

X Run: 37, Metric: 1

**Selection Parameters**

X :Factor: service, Range: 0.8 - 0.95

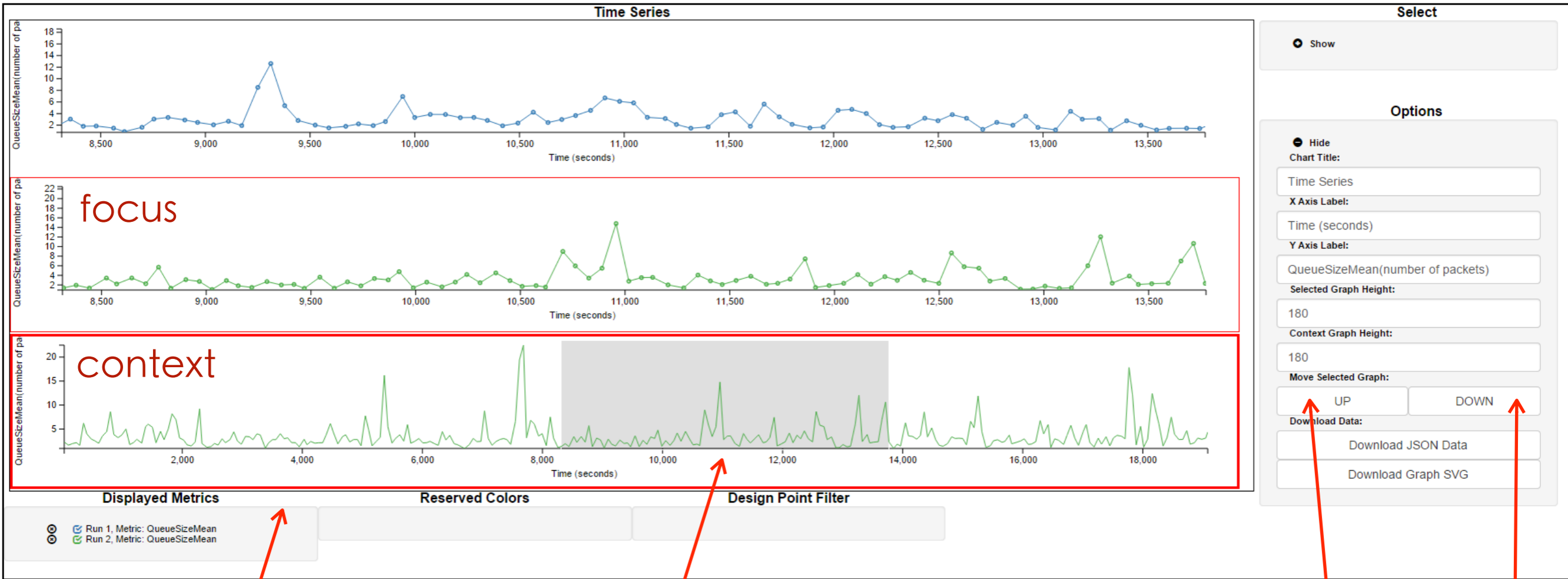
# SAFE Visualization: Time Series (selection)



Colors available for plotting



# SAFE Visualization: Time Series (options)

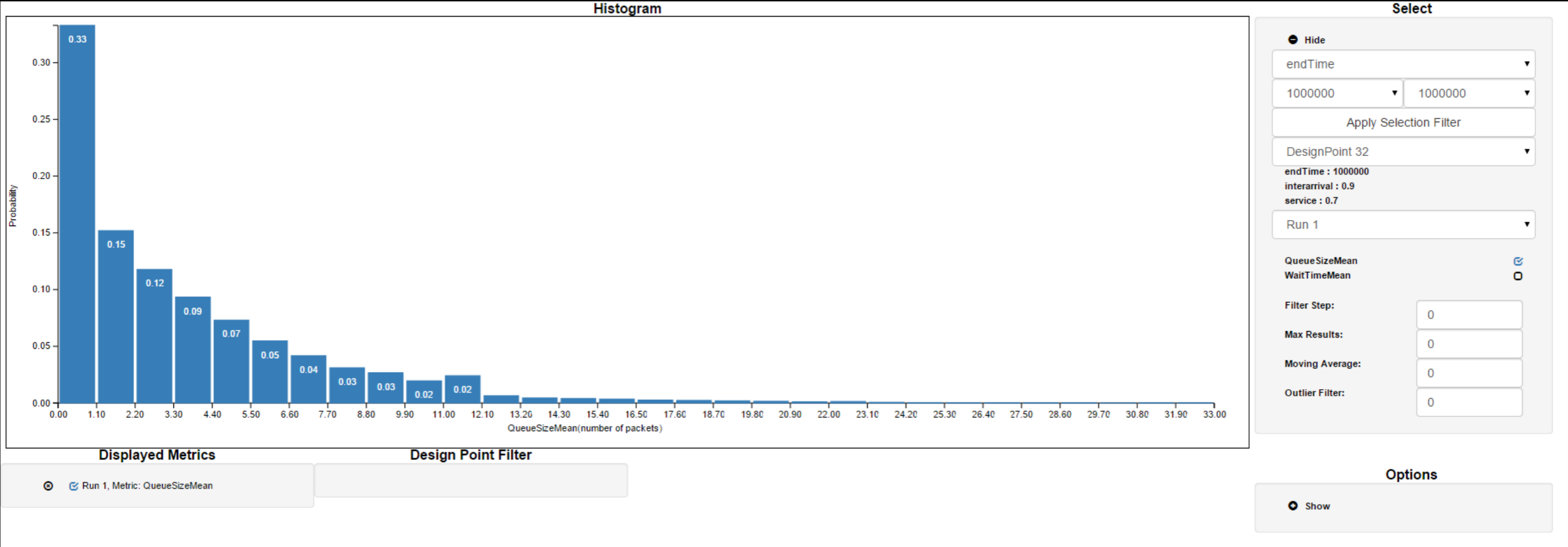


Selected facet

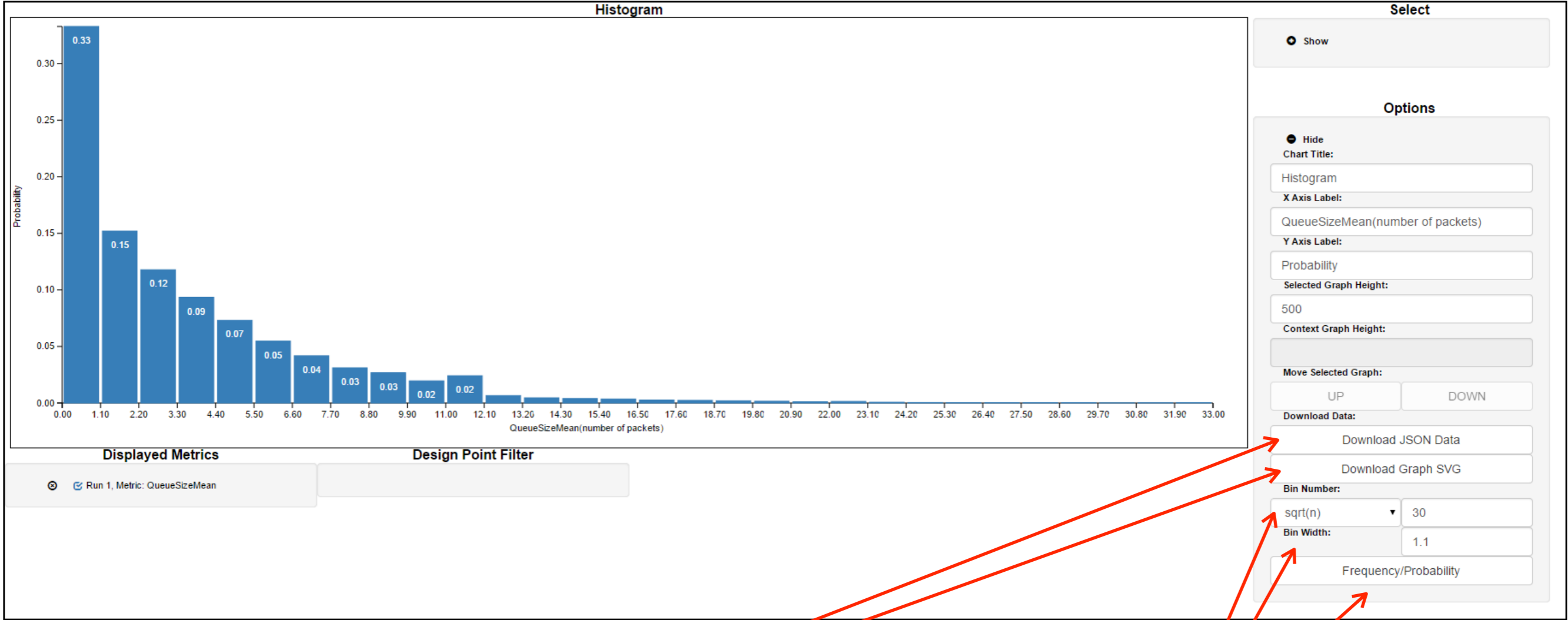
brush

Facet movement

# SAFE Visualization: Histograms (selection)



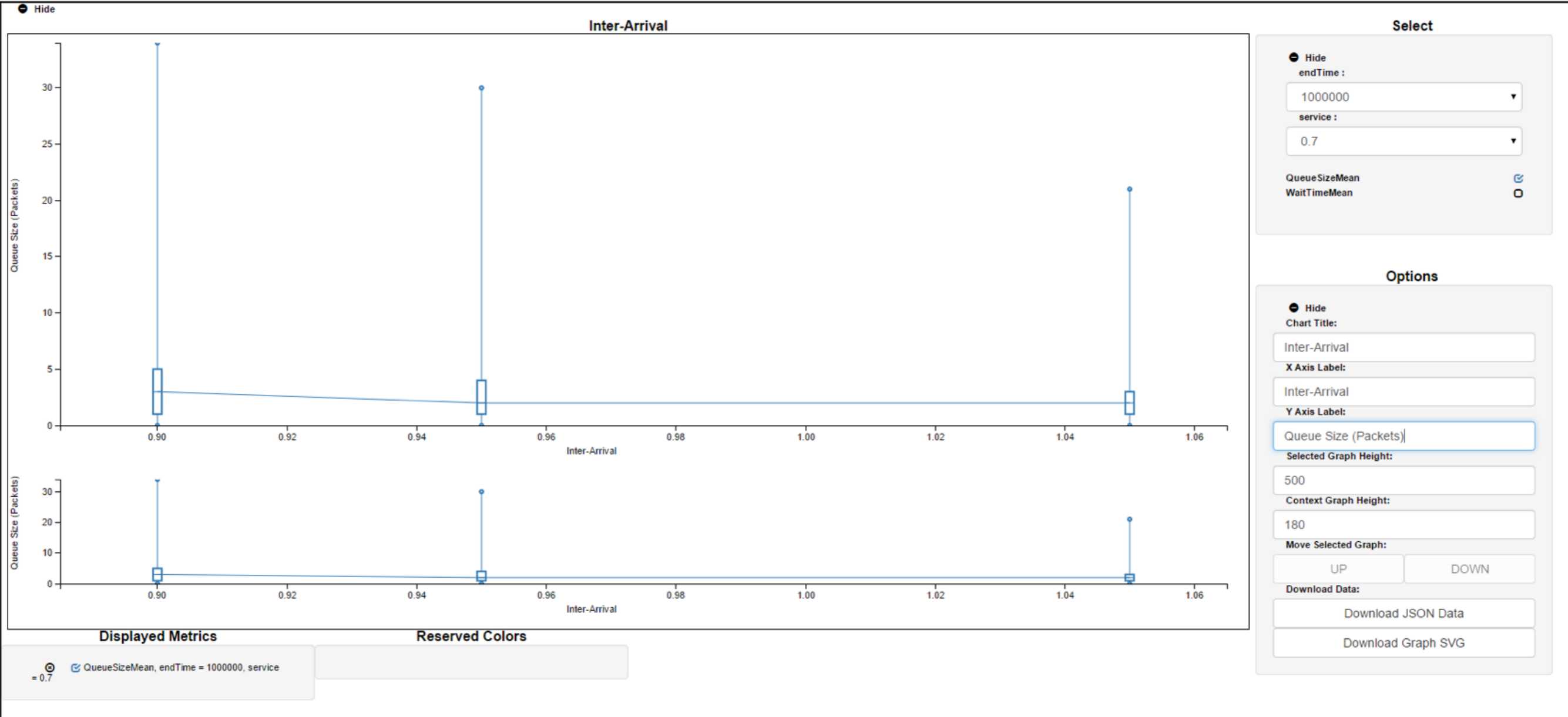
# SAFE Visualization: Histograms (options)



Export options

Contextual options

# SAFE Visualization: Box-and-Whiskers



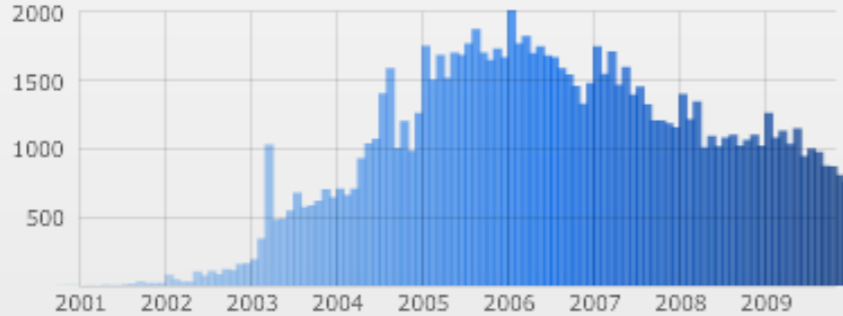
# Advanced Visualizations: Spiral Graph

## Time Oriented Cyclical Data

### 10 years of Wikipedia

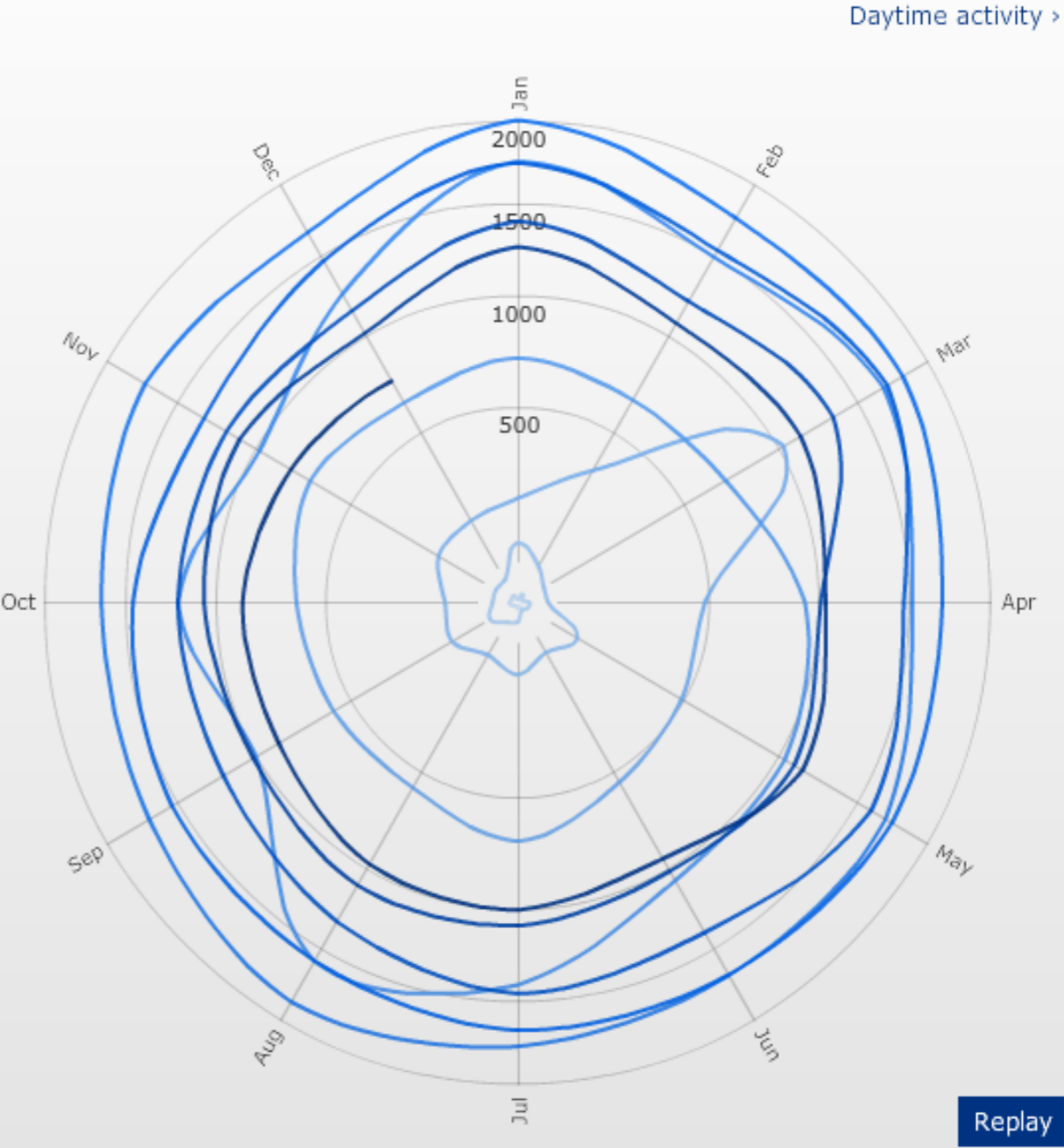
New Wikipedites

The monthly number of new Wikipedites contributing at least ten edits has been falling steadily since 2006. If the trend continues, there will be barely any new users within just a few years.



- Total number of contributors
- Active Wikipedites
- Very active Wikipedites
- New Wikipedites**
- Edits per month
- Edits per entry
- Total number of entries
- New entries each day
- Total number of words

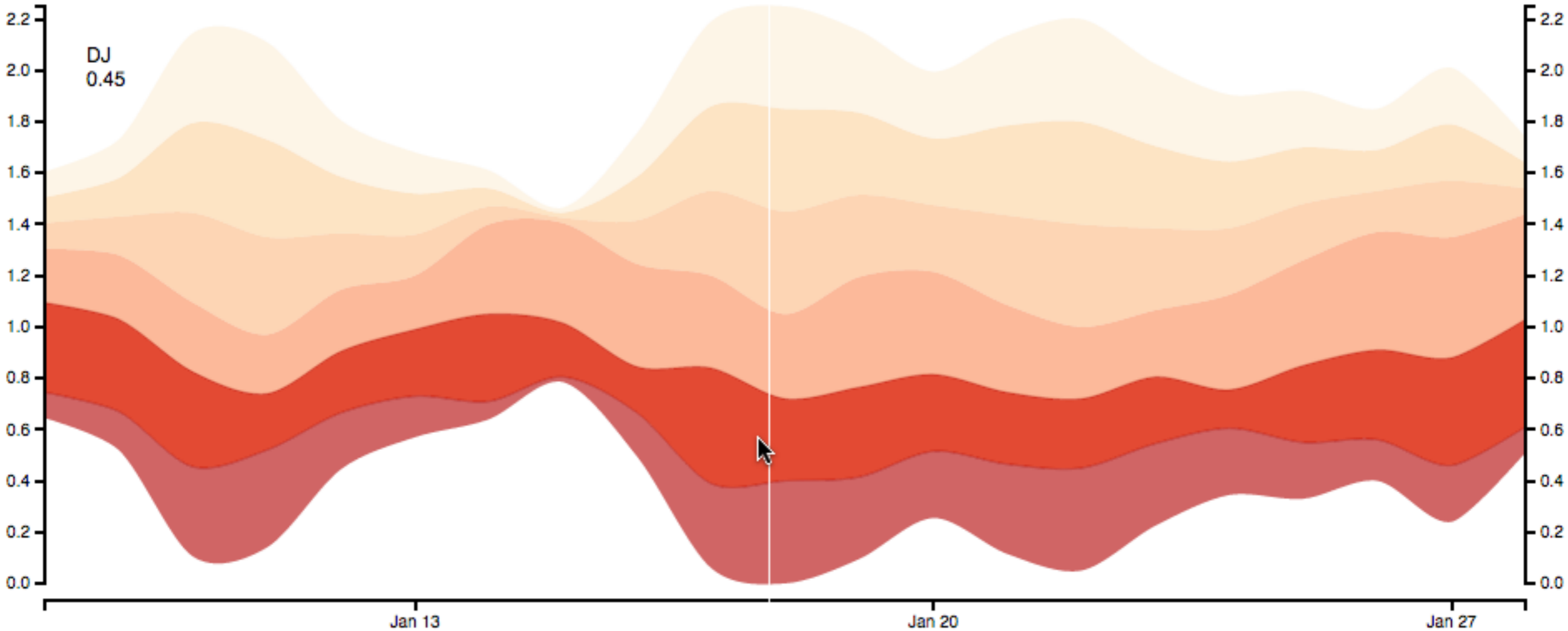
Source: stats.wikipedia.org



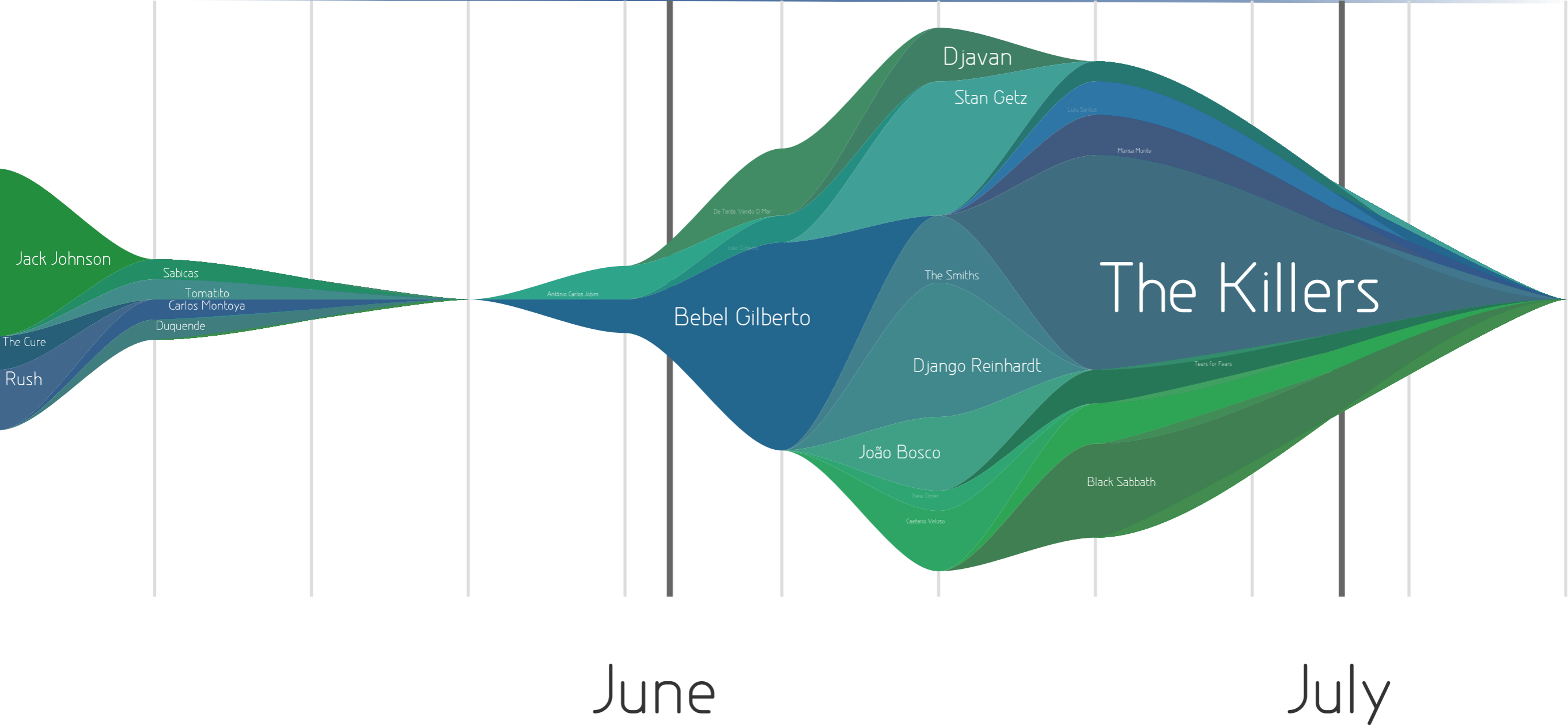
A recurrence of epochs

# Advanced Visualizations: Stream Graph

## Time Oriented Data



# Unrelated Example of StreamGraph



Made with [lastgraph.aeracode.org](http://lastgraph.aeracode.org) from last.fm user profile